TECHNICAL report

USA-BRDEC-TR // 2510

Engine Cooling System Survey of Military Antifreeze MIL-A-46153 Field Performance (U)

Prepared by
Dwayne Davis

Report Date
July 1991

United States Army
Belvoir Research, Development and Engineering Center
Fort Belvoir, Virginia 22060-5606

Destroy this report when it is no longer needed.
Do not return it to the originator.

The citation in this report of trade names of commercially available products does not constitute official endorsement or approval of the use of such products.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	July 1991	Final

4. TITLE AND SUBTITLE

Engine Cooling System Survey of Military Antifreeze MIL-A-46153 Field Performance (U)

5. FUNDING NUMBERS

6. AUTHOR(S)

Dwayne Davis

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Belvoir Research, Development and Engineering Center
Materials, Fuels and Lubricants Directorate
ATTN: STRBE-VF
Fort Belvoir, VA 22060-5606

8. PERFORMING ORGANIZATION REPORT NUMBER

2510

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

POC: Dwayne Davis, 703/664-4594

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Distribution unlimited; approved for public release.

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

This report gives results of a field survey conducted during April through June 1988 to determine the effectiveness of Military Specification antifreeze MIL-A-46153. Participation included Army, Air Force, and Navy organizations. The questionnaire is included as an appendix.

14. SUBJECT TERMS

antifreeze, MIL-A-46153, component replacement frequency, water pump, engine cooling system, ethylene glycol, questionnaire, military antifreeze, engine coolant

15. NUMBER OF PAGES

36

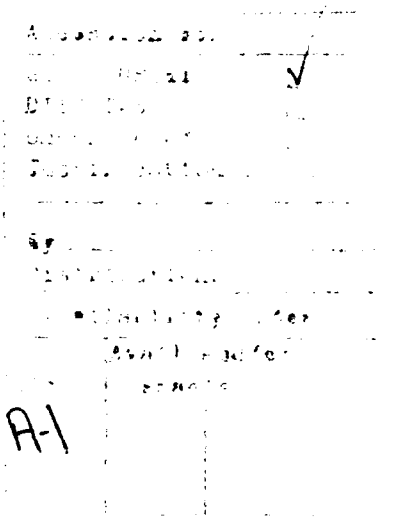
16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

Report Number 2510

Engine Cooling System Survey of Military Antifreeze MIL-A-46153 Field Performance (U)

Prepared by
Dwayne Davis



US Army Belvoir RD&E Center
Materials, Fuels and Lubricants Directorate
Fort Belvoir, Virginia 22060-5606

July 1991

Table of Contents

Section I
Background

The purpose of this survey was to determine whether or not the current formula for Military Specification antifreeze, MIL-A-46153, requires improvement. The present formula is based on a compositional specification developed in the late 1950s for use in gasoline and diesel engines. In recent years, because of higher operating temperature engines and increased usage of aluminum components, the corrosion protection ability of MIL-A-46153 was placed in doubt.

Initially, the survey was to be distributed among a small number of Army depots with large motorpools located throughout the Continental United States (CONUS). It was felt that these depots, where major engine repairs are performed, would provide good data on typical cooling system problems found in the military environment. Later, several US Air Force Base motorpools and one Naval Sea Command were included in the survey. The additional installations were located overseas and in CONUS. The addition of the Naval Sea Command were included in the survey. The additional installations were located overseas and in CONUS. The addition of the Naval Sea Command motorpool and Air Force motorpools considerably increased the amount of data and allowed for better statistical analysis.

Section II
Approach

This survey was conducted during April through July 1988. It consisted of a questionnaire (see Appendix A), with 25 questions pertaining to cooling system-related overhauls and cooling system component replacement frequencies. Of the 25 questions, only 7 were selected for statistical analysis. The questions chosen were those which best characterized the field performance and usage of military antifreeze. The survey was distributed to 1 Naval Sea Command, 8 Army depots, and 91 Air Force Bases (see Appendix B). Of the 100 participants, 13 were not included in the data analysis due to their usage of antifreeze other than MIL-A-46153. This was done to eliminate field problems associated with the MIL-A-11755 arctic-type antifreeze, non-military antifreezes, and the mixing of incompatible antifreezes. Of the remaining 87 participants, a few left questions blank, thereby again reducing the total number of responses. For this reason, the total number of responses is given for some questions.

The number and types of vehicles varied significantly among the 87 motorpools. Some participants listed their approximate motorpool size, although this was not a required response. From the available responses, motorpool size ranged from 57 to 1,500 vehicles. Some of the vehicle types listed included heavy construction equipment, M-series tactical trucks, firetrucks, airplane refuelers, snowplows, commercial automobiles, commercial pickup trucks, commercial vans, commercial buses, and special purpose vehicles. For the statistical analysis of the seven questions, straightforward averages and average percentages of the total were calculated. Responses to selected questions #2, #3, #9, #10, #15, #16, and #18 are summarized below. Appendix C contains pie charted results.

COOLING SYSTEM COMPONENTS REPLACED PER YEAR

Responses to question #2 revealed that small cooling system components are replaced more often, per year, than other components (See **Table 1**). Components such as thermostats, hoses, radiator caps, radiator drain plugs, and engine block drain plugs were among the smaller items that appear to be more susceptible to degradation as compared to larger components such as water pumps, radiators, and engine blocks. Radiators and water pumps were almost tied for the second most frequently replaced component per year, comprising 22% and 23% of the total, respectively. Heater cores represented 13% of the components replaced and engine blocks only 3%.

Table 1. Average Percentage of Total Cooling System Components Replaced In One Year

	Radiators	Heaters	Water Pumps	Blocks	Other
Average	21.6%	12.9%	22.6%	2.5%	38.7%
standard deviation	21.1%	12.9%	18.1%	7.3%	31.2%
95% confidence limits, ±	4.4%	2.8%	3.9%	.6%	6.7%
Responses	86	84	84	84	82

For this survey, the average total number of components replaced per year was 70± 26 components at the 95% confidence level. The large uncertainty is due to the several different motorpool vehicle sizes sampled. Only a few participants provided total vehicle numbers but, from these few, large differences in the total vehicle sizes can be seen in **Table 2**.

Table 2. Motorpools Sampled/Components Replaced in One Year

Radiators	Heater Cores	Water Pumps	Blocks	Other	Total No. Vehicles
0	0	0	0	0	91
25	0	12	3	75	611
15	4	30	0	0	660
60	20	0	0	0	550
0	0	0	0	0	57
8	25	30	1	150	511

COMMON COMPONENT REPLACEMENT PROBLEMS

For question #3e, the category "others" was eliminated from statistical analysis because the responses included a broad range of components and no generalizations could be made. The remaining categories received common responses which were tabulated in Table 3.

Table 3. Component Replacement Totals

	Plugging	Corrosion	Deposits	Leaking
Radiators	22	38	24	45
Heaters	7	19	6	19
Water Pumps	1	8	2	45
Engine Blocks	2	0	3	0
Responses	83	84	84	84

From the results, over half the total number of respondents, 45 out of 84, listed leaking as a common radiator problem. This suggests MIL-A-46153 may not provide sufficient corrosion protection. Radiators were also replaced because of plugging and deposits in nearly equal numbers, but only approximately half the number of times that corrosion and leaking occurred. The totals suggest corrosion tends to cause radiator leakage, and deposit formation promotes radiator plugging.

Similar conclusions can be made to explain the results for heater cores and the engine blocks. The heater is essentially a smaller version of the radiator, so its problems should be similar to those of the radiator. For engine blocks, significant corrosion, and thereby leaking, is not expected due to thickness of the block itself. This fact is made evident by the zero number of responses for corrosion and leaking. However, deposits from rust or depleted inhibitors could very well plug the narrow passages of an engine block water jacket. These assumptions are reasonable, but exclude the possibility of radiator leakage due to external forces, unrelated to the coolant, such as severe vehicle vibrations sometimes found in the off-highway military environment. Such stresses can weaken soldered joints and also cause radiator leakage.

Looking at the water pump data, leaking outnumbers the other replacement problems by a substantial amount. Plugging and deposits are not typical problems of a water pump due to the pump's inherent design. The corrosion totals do not entirely explain the large replacement frequency due to leaking, as in the case of radiators and heater cores. Therefore, leaking may be attributed to reasons other than corrosion such as normal wear. For example, pump bearings and seals eventually become worn after normal service and cause leakage. In addition, many water pump designs found in light trucks and cars incorporate mechanical, belt-driven fans which are attached to the pump drive shaft. If the bearings become loose due to normal wear, pump seal failure can be accelerated by additional torque stresses induced by misalignment from the worn bearings.

MIL-A-46153 FIELD USAGE CHARACTERISTICS

This portion of the report summarizes responses to questions #9, #10, #15, #16, and #18. From question #15, 68 responses gave an average 3.06 years as the replacement frequency of MIL-A-46153. This is approximately one year shy of the currently recommended maximum of four years. For question #9, out of 86 responses only 7 (8%) use the military antifreeze extender, MIL-A-53009. The remaining 79 (92%) do not. The reasons given for not utilizing MIL-A-53009 varied , but the most common reasons were due to users either not knowing MIL-A-53009 existed or its proper purpose. For question #10, asking the participant's opinion concerning MIL-A-46153 effectiveness, the responses were designated "positive" or "negative" so a generalization could be made. Out of the 83 responses, 66 (80%) were rated positive and 17 (20%) were rated negative. Some of the responses were as follows:

"No problems noted."

"Good and effective."

"It [MIL-A-46153] is good antifreeze for general purpose automotive use but probably needs additives to prevent deposit build-ups."

"Serves the purpose."

"We have had no problems with antifreeze which resulted in component failures due to corrosion, deposits, or breakdown of coolants."

"Satisfactory."

"I feel it [MIL-A-46153] needs to be upgraded to a better performing antifreeze to meet today's needs."

"It [MIL-A-46153] is very good antifreeze."

"Not effective. Seems to break down too quickly. No additives for lubrication or corrosion. Not compatible with aluminum components."

"Adequate, but requires additional corrosion inhibitors."

"It [MIL-A-46153] could be improved. Should be of the quality equivalent to . . . some of the good commercial types."

"Good, but a new MIL-spec for aluminum block and cylinder heads is needed."

"Ineffective in newer vehicles."

"Works well, if the maintenance activity maintains it [MIL-A-46153] properly. The steel engine blocks and heads do rust so a rust inhibitor should be used occasionally. Aluminum blocks and heads get hotter than their normal operation temperature. The mixture percentage should be changed when it is installed in engines with aluminum heads or blocks to have a greater mixture of antifreeze to water. This "richer" mixture should only be used in tropical climates."

"More rust inhibitor should be added to the new material."

"Good - But think 3 years maximum use would greatly reduce component failures."

"Very good."

"It [MIL-A-46153] is very effective. We are required to replace every four years, but find we are replacing good antifreeze."

Responses #3, #7, and #9 through #16 were rated negative because users recommended changes to the current specification. For question #18, out of the 80 responses, the average percentage for unscheduled vehicle maintenance, with 100% being the maximum, attributed to cooling system trouble was 5.12%. For question #16, out of 75 responses, 60 (80%) use the military antifreeze test kit, A-A-51461, to check reserve alkalinity and the remaining 15 (20%) do not. As in the case for the MIL-A-53009 extender, the limited usage may reflect a lack of awareness of the test kit's existence.

Section III
Conclusion

The results of this survey, for the most part, reveal the military specification antifreeze MIL-A-46153 to be effective in the military environment, with 80% of the users declaring that the current MIL-A-46153 gives satisfactory field performance. However, 20% of the users feel that the current MIL-A-46153 antifreeze needs improving. The opinion of these users, coupled with the relatively high corrosion and leaking problems for radiators found in Table 3, page 3, warrants further investigation of MIL-A-46153 field performance. In addition, some user responses still leave doubts of MIL-A-46153's aluminum protection effectiveness. A second survey is recommended which will give greater detail of MIL-A-45153's actual effectiveness. This first survey can be used as a guidepost for the second survey. The second study would have similar but more explicit questions which will help obtain more definitive answers. For example, specific questions need to be asked pertaining to motorpool size and the majority types of vehicles serviced.

Appendix A

Survey of Replacement Frequencies for Engine Cooling System Components

BACKGROUND

MIL-A-46153 antifreeze is a compositional specification that was developed in the late 1950s for both gasoline and diesel fueled tactical and combat vehicles and equipment. Since then, vehicle and engine technologies have advanced. Engine operating temperatures have increased and engine blocks, radiators, and other cooling system components are made of different materials such as aluminum and aluminum alloys. The current formulation for MIL-A-46153 may or may not be satisfactory in protecting present cooling system components deterioration. Only direct feedback from field users will enable us to determine whether the present formulation needs to be adjusted to the differing conditions.

OBJECTIVE

To obtain information on cooling system related overhauls and replacement frequencies for potential upgrading of the military's standard antifreeze.

INSTRUCTIONS

Please answer the questions yes, no, as directed or don't know. Answer the questions to the best of your knowledge. If you need more space, continue on the back of the form.

If you OVERHAUL cooling systems, answer questions 1 - 12.

If you MAINTAIN cooling systems, answer questions 13 - 25.

OVERHAULERS

1. On what vehicles do you overhaul the cooling systems?

_____

_____

_____

_____

_____

2. Approximately how many cooling system components do you replace per year?

Radiators _____

Heaters/cores _____

Water pumps _____

Engine Blocks _____

Other (thermostats, etc.) _____

3. What is the most common reason/problem that occurs that the components must be replaced? (List the component next to the problem.)

a. Corrosion _____ _____ _____ _____

b. Deposits _____ _____ _____ _____

c. Leaking _____ _____ _____ _____

d. Plugging _____ _____ _____ _____

e. Others? Please describe. _____

_____

_____

_____

_____

4. If corrosion and deposits have been the main reason for replacing components, do you see it in **all** types of vehicle cooling systems? _____ OR only a **few** types of vehicle cooling systems? _____ If yes to a few, which engines?

_____

_____

_____

5. Do you replace cooling system components more often on certain types of vehicle cooling systems? _____ If yes, please list the engines and the cooling system component(s).

Vehicle/Equipment	Component(s)
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

6a. Do you test the antifreeze with the test strip to see if it is any good when you remove it from the cooling system at overhaul? _____

6b. Do you reuse antifreeze from overhauled cooling systems? Explain.

_____

_____

_____

_____

7. For overhauled cooling systems going into storage or preservation, are there special procedures used other than refilling with MIL-A-46153? _____ If yes, explain.

_____

_____

_____

_____

_____

8. Do you always use MIL-A-46153 antifreeze in military vehicles/equipment? _____ If not, what other products are used and why?

9. Are you using antifreeze/coolant extender, MIL-A-53009 (NSN 6850-01-160-3868) in the cooling system of military vehicles/equipment? _____ If yes, do you record the date that the extender was added to the system on a DD Form 314 (Preventive Maintenance Schedule and Record)? _____ If no, please explain.

10. What do you think about the effectiveness of MIL-A-46153 antifreeze?

11. If there are any comments, questions, or other related information that would assist in this survey solicitation, please provide below.

12. In order to provide you with a copy of the results of this questionaire, please provide the address where it should be sent.

_____

_____

_____

_____

Please return this questionnaire to: (label attached)

Commander

Belvoir Research, Development, and Engineering Center

ATTN: STRBE-VFH (Smith)

Fort Belvoir, VA 22060-5606

Questions? Call DSN 354-4325 or Commercial 703/664-4325

THANK YOU FOR YOUR PARTICIPATION

MAINTENANCE

13. Do you maintain inspection data on all military vehicles/equipment that you are responsible for maintaining? _____ If no, which vehicles do not have maintenance data? _____

_____

_____

_____

_____

14. Do you always use MIL-A-46153 antifreeze in military vehicles/equipment? _____ If not, what other products are used and why? _____

_____

_____

_____

_____

15. How many months do you go between replacements of MIL-A-46153 antifreeze/coolant? _____

16. Do you ever use the Test Kit for Reserve Alkalinity (NSN 6630-01-011-5039) to see if the antifreeze/coolant is still good before replacing it? _____ If yes, do you record your results from the test strip on a DD Form 314 (Preventive Maintenance Schedule and Record)? _____ If no, please explain.

_____

_____

_____

_____

_____

17. Are you using antifreeze/coolant extender, MIL-A-53009 (NSN 6850-01-160-3868) in the cooling system of military vehicles/equipment? _____ If yes, do you record the date that the extended was added to the system on a DD Form 314 (Preventive Maintenance Schedule and Record)? _____ If no, please explain.

_____

_____

_____

_____

_____

18. Of all the vehicles coming in for unscheduled maintenance, estimate the percentage of vehicles with cooling system trouble. _____%. Which vehicle(s) seems to have the most cooling system trouble? _____

_____

_____

Which equipment seems to have the most cooling system trouble?

_____

_____

_____

19. What is the most common reason/problem that occurs that the components must be replaced? (List the component next to the problem.)

a. Corrosion _____ _____ _____ _____

b. Deposits _____ _____ _____ _____

c. Leaking _____ _____ _____ _____

d. Plugging _____ _____ _____ _____

e. Others? Please describe. _____

_____

_____

_____

_____

20. How many cooling system components do you replace per year?

Radiators	_____	_____	_____
Water Pumps	_____	_____	_____
Heaters/Cores	_____	_____	_____
Engine Blocks	_____	_____	_____

Other (thermostats, hoses, etc.)(please describe) _____

_____

_____

_____

_____

21. If corrosion and deposits have been the main reason for replacing components, do you see it in **all** vehicle/equipment cooling systems? _____ OR only a **few** vehicle cooling systems? _____ If yes to a few, which vehicles?

_____

_____

_____

22. Do you replace cooling system components more often on certain vehicles? _____ If so, please list the vehicle and the cooling system component(s).

Vehicle/Equipment	Component(s)
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

23. What do you think about the effectiveness of MIL-A-46153 antifreeze?

_____

_____

_____

_____

_____

24. If there are any comments, questions, or other related information that would assist in this survey soliciation, please provide below.

_____

_____

_____

_____

_____

25. In order to provide you with a copy of the results of this questionnaire please provide the address where it should be sent.

_____

_____

_____

_____

_____

Please return this questionnaire to: (label attached)

Commander

Belvoir Research, Development, and Engineering Center

ATTN: STRBE-VFH (Smith)

Fort Belvoir, VA 22060-5606

Questions? Call DSN 354-4325 or Commercial 703/664-4325

THANK YOU FOR YOUR PARTICIPATION

Appendix B
Survey Distribution List

63 MAW/LGTM (MSgt Tremblay)
Norton, AFB, CA 92409

Mr. Steve Jacobs
HQ AAL/LGTV
Elmendorf AFB, AK 99506

18 TRANS/LGTM
Kadena Air Base
APO San Francisco 96239

134th Air Refueling Group/LGTM
McGhee Tyson Airport
Knoxville, TN 37950-5000

177 FIG/LGTM
400 Langley Road
ANGB, ACY IAP
Pleasantville, NJ 08232-9500

TECOM/LGTV
ATTN: Dale
P O. Box 4247, Hangar 312
PAFB, FL 32925

Commander
Anniston Army Depot
ATTN: SDSAN-DM-PP
Anniston, AL 36201-5010

475 TRNSPS/LGTM
Yokota ABS, Japan
APO San Francisco 96328

101 TAC CON SQ
Skyline Drive
Worcester, MA 01605-2898

SMS Brown
157 AREFG/LGTM
Pease AFB, NH 03803-6526

401 TFW/LGTM
APO New York 09283-5000

36 TFW/LGTM
APO New York 09132-5000

158th RMS/LGTM
BIAP, VT 05401

172 RMS/LGTM
P. O. Box 5810
Jackson, MS 39208-0810

179th Tactical Airlift Group
ATTN: MSgt Greg Roberts
Mansfield Lahm Airport
Mansfield, OH 44901-5000

130 TAG/LGTM (Vehicle Maintenance)
Yeager Airport
Charleston, WV 25311-5000

132 TFW/RMS IOWA ANG
ATTN: SMSgt Kenneth Croat
Vehicle Maintenance Superintendent
Building 105
3100 McKinley Avenue
Des Moines, IA 50321-2799

119th FIG NDANG
Box 5536
Fargo, ND 58105-5536

182 TAC Air Support Group
Greater Peoria Airport
Peoria, Il 61607

Maryland Air National Guard
2701 Eastern Boulevard
Baltimore, MD 21220

105th Military Airlift Group/LGT
Steward Air National Guard Base
One Militia Way
Newburgh, NY 12550-5043

133 RMS/LGTM
Surface Transportation
Minneapolis-St. Paul International Airport
St. Paul, MN 55111-4098

159 RMS/LGTM
ATTN: SMS Latakes
Louisiana Air National Guard
United States Naval Air Station
New Orleans, LA 70143-5000

15 TRANS SQ/LGTM
Hickam AFB, HI 96853-5000

836 TRANSPS/LGTM
ATTN: CMSgt Bowers
Davis Monthan AFB, AZ 85707-5000

36 TRANS SQ/LGTM
Bitburg AB Gc
APO New York 09132

HQ-AU/LGM
ATTN: Allen McLeroy
Maxwell AFB, AL 36112-5001

833 TRANS/LGTM
Vehicle Maintenance
Building 198
Holland AFB, NM 88330

354th TRANS SQ/LGTM
Myrtle Beach AFB
Myrtle Beach, SC 29579-5000

831 TRNSS/LGTM
ATTN: Mr. Upperman
George AFB, CA 92394-5000

HQ USCENTAF/LGT
Shaw AFB, SC 29152

KTTC/LGTM
ATTN: SMS Elbert Dargan
Keesler AFM, MS 39534-5000

71 ABG/LGTV
Building 297 - NW - ST
Vance AFB, OK 73705-5000

3636 CCTW/LGT
ATTN: SSgt Pearson
Fairchild AFB, WA 99011

31st TRANS SQ/LGTM
Homestead AFB, FL 33039

24th TRANS SQ/LGTM
ATTN: Delbert Turner, Jr.
APO Miami, FL 34001-5000

832 TRNS/LGTM
ATTN: Mr. Conrad
Luke AFB, AZ 85309

834 TRANS SQ
ATTN: Vehicle Maintenance Superintendent
Hurlburt Field, FL 32544

3246 TESTW/LGT
ATTN: Vehicle Maintnenance Officer
Eglin AFB, FL 32542

366 TFW/LGTM
Mountain Home AFB, ID 83648

27th TTANS SQ/LGTM
Cannon AFB, NM 88103-5271

440 TAW
ATTN: LGTM Fred Krenz
300 E. College Avenue
Milwaukee, WI 53207

934 TAG/LGTM
ATTN: Roger Hanson
Minneapolis-St. Paul International Airport
Minneapolis, MN 55450-5000

110 TASGP
3367 W. Dickman Road
Battle Creek, MI 49015-1291

180 RMS/LGTM
Toledo Express Airport
Swanton, OH 43558-5002

6948 Electronic SCTY SQ/LGTM
Kelly AFB, TX 78243

3480th TRANS/LGTM
Goodfellow AFB
San Angelo, TX 76908

CC HC MP 736 VH
MacDill AFB, FL 33601

292 Combat Communications SQ/LGTM
75 Kuleana Street
Kahului, HI 96732-2330

6514 TRNSPS/LGTM
Edwards AFB, CA 93523

323 TRNSPS/LGTM
ATTN: MSgt Garcia
Mather AFB, CA 95655-5000

12 TRNS/LGTM
ATTN: Vehicle Maintenance
Randolph AFB, TX 78150

3700 TRNSPS/LGTM
Lackland AFB, TX 78236-5000

HQ SARPMA/LGT
P. O. Box 8295
Wainwright Station
San Antonio, TX 78208-0295

56 TRNSPS/LGTM
Building 500
MacDill AFB, FL 33608-5000

23 TRANS/LGTM
England AFB, LA 71311-5004

211th E.I.S.
ATTN: TSgt Moore
40 Dept of Military Affairs
Annville, PA 17003-5002

SDSTE-ASE-M
ATTN: George E. Frailey
Building 510
Tooele Army Depot
Tooele, UT 84074

435 TRANS/LGTM
APO New York 09097-5000

139 TAG
ATTN: SMS Donald L. Lewis
Box 3247
Pony Express Station
St. Joseph, MO 64503-3247

94 CSG/LGTM
Dobbins AFB, GA 30069-5270

3 MAPS/TRMV
Scott AFB, IL 62225

926 TFG/LGTM
NAS
New Orleans, LA 70143-5400

1605th TRANS SQ
ATTN: Vehicle Maintenance Superintendent
Vehicle Maintenance Stop 39
APO New York 09496

7625 Logistics SQ/LGTM
Building 8122
USAF Academy, CO 80840

298 ATCF/Banking Sands, HI
ATTN: Msgt H. K. Maeda
P. O. Box 610
Kekaha, HI 96762

1606 TRANS/LGTM
ATTN: Vehicle Maintenance
Kutland AFB, NM 87185

3245 LG/LGTM/MC&A
Hanscom AFB, MA 01731-5000

Letterkenny Army Depot
ATTN: Glen P. Baer
Building 351, MVPR 50340
Chambersburg, PA 17201

Commander
Anniston Army Depot
Directorate for Engineering & Logistics
ATTN: SDSAN-DEL-DE
Anniston, AL 36201-5047

Commander
Seneca Army Depot
ATTN: D/Logistics SDSSE-LME
Romulus, NY 14541-5001

Commander
Letterkenny Army Depot
ATTN: SDSLE-MMSS (Mike Glover)
Chambersburg, PA 17201-4150

ANG Training Site
ATTN: CMSgt Lee
P. O. Box 1300
Gulfport, MS 39502-1300

60 TRNSS/LGTM
Travis AFB, CA 94535

136 RMS/LGTM
Hensley Field
Dallas, TX 75211-9503

CTTC/LGT
Chanute AFB, IL 61868

82 FTW/LGTM
Williams AFB, AZ 85240-5000

910 TAG/LGTM
Youngstown Municipal Aripon
Vienna, OH 44474-5000

STTC/LGTM
Stop 13
Sheppard AFB, TX 76311

14th FTW/LGTM
Columbus AFB, MS 39701-5000

290 JCSS/LGTM
ATTN: TSgt Julio Sosa
MacDill AFB, FL 33608-5000

159 RMS/LGTM
ATTN: SMS L. J. Gonzales
P. O. Box 5510
Kirtland AFB, NM 87185-5510

Air Force Orientation Group/LGTM
Gentile AFS, OH 45444

64 FTW/LGTM
Building 366
Reese AFB, TX 79489

51 TRNSPS/LGTM
Osan AB, ROK 97230

Naval Sea Systems Command
ATTN: Code 56X33
Washington, DC 20362

347 TFW/LGTM
Moody AFB, GA 31699-5000

439 ADG/LGTM
Westover AFB
Chicopee, MA 01022

JCSE-CSGMD
ATTN: SMSgt Kern
MacDill AFB, FL 33608

928 TAG/LGTM
O'Hare ARFF, IL 60666-5000

914 TAG/LGTM
Niagara Falls International Airport
Niagra Falls, NY 14304-5000

262 CCSQ/LGTM
Building 3
4001 Williamson Way
Bellingham, WA 98226-8497

834 TRANS SQ
ATTN: Vehicle Maintenance Superintendent
Hurlburt Field, FL 32544

Commander
Sierra Army Depot
ATTN: Mr. Robinson
SDSSI-EMD
Herlong, CA 96113-5140

105 TCS
Route 2, Box 153A
Cheney, WA 99004-9659

1003 TRNSPS/LGTM
ATTN: TSgt Romney Sprecher
Peterson AFB, CO 80914

911th Tactical Airlift Group/LGTM
Greater Pittsburgh International Airport
Pttisburgh, PA 15231-5000

215th EIS/LGT
ATTN: MSgt Hawkins
2107 112th Street, SW
Everett, WA 98024-3502

Appendix C
Pie Charted Results

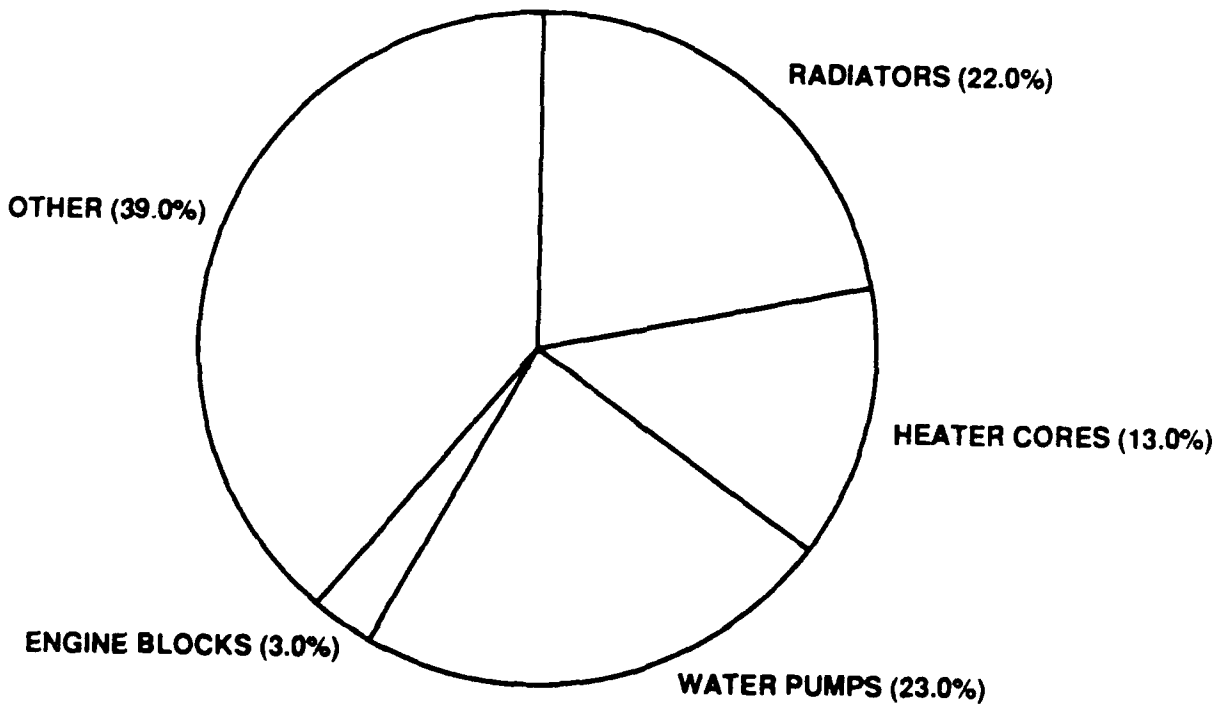


Figure C-1. Average Percentage of the Total Number of Components Replaced per Year

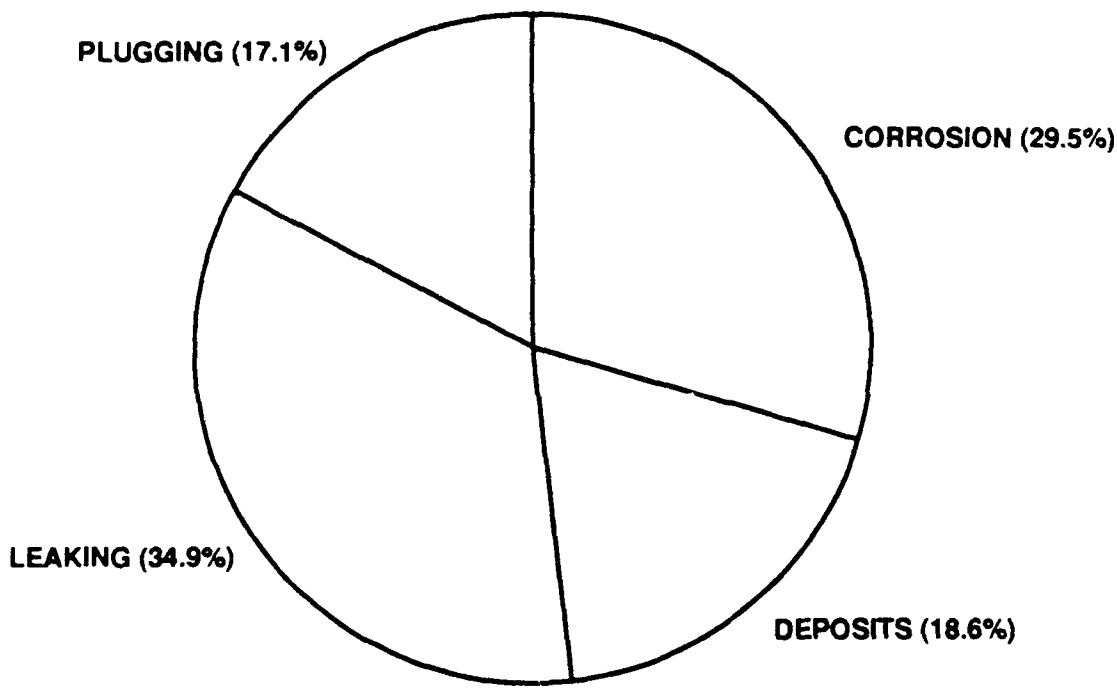


Figure C-2. Common Radiator Problems

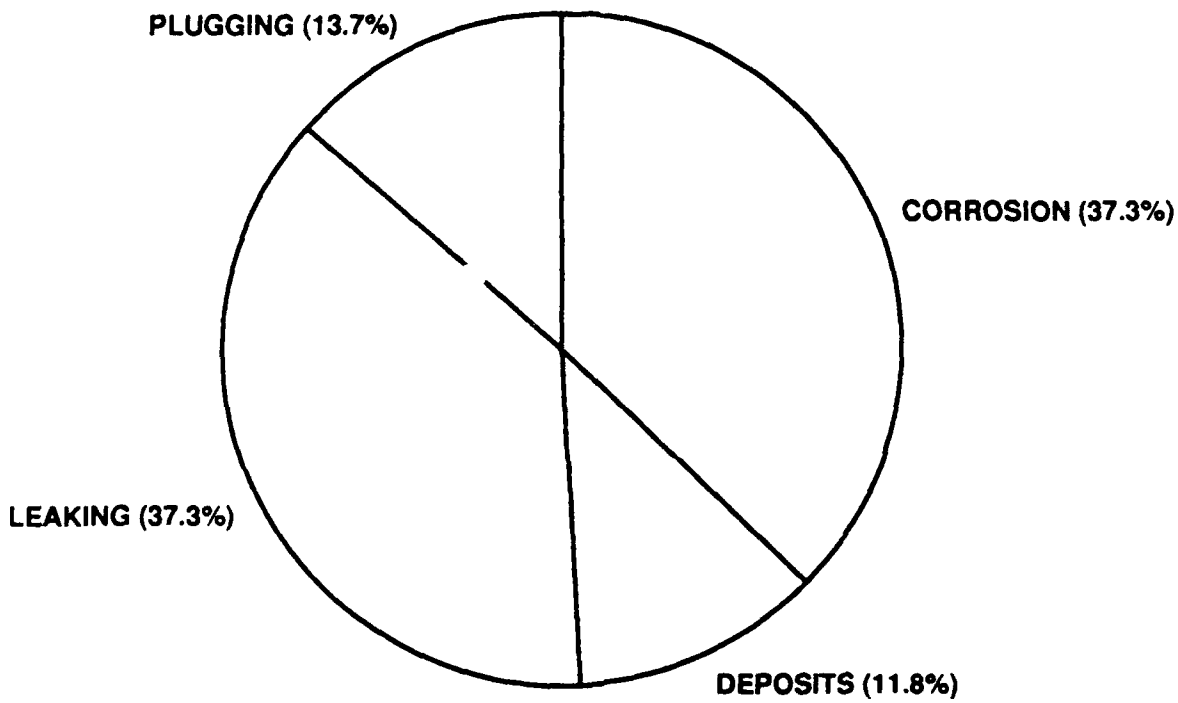


Figure C-3. Common Heater Core Problems

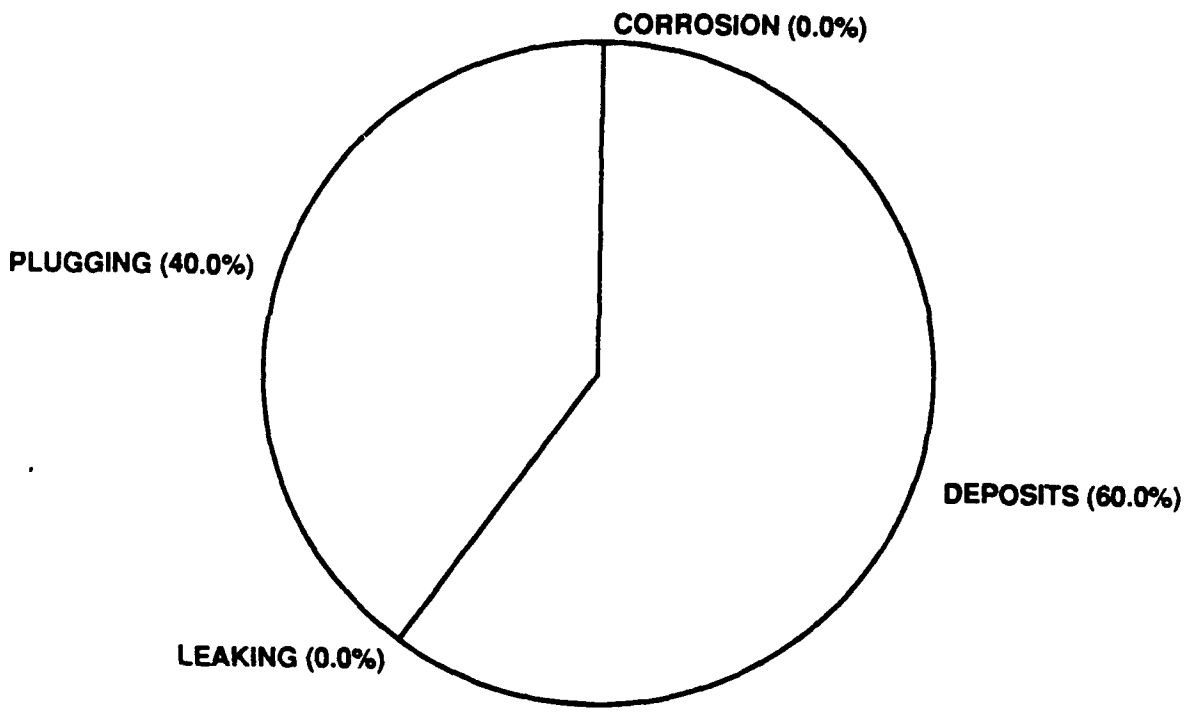


Figure C-4. Common Engine Block Problems

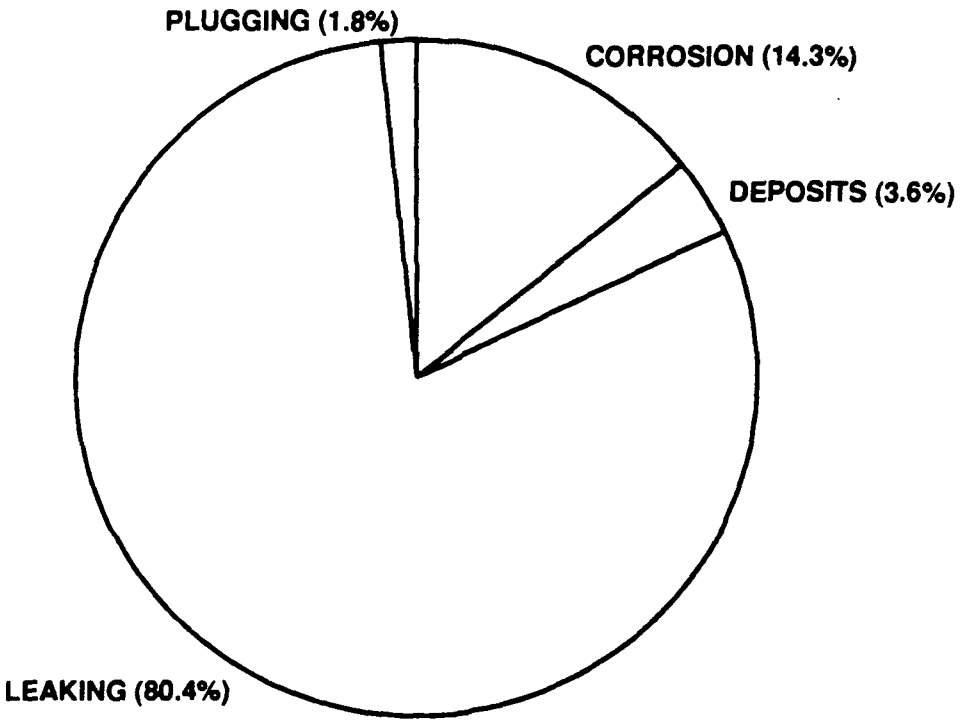


Figure C-5. Common Water Pump Problems

Distribution for Report No. 2510

Department of the Army

2 HQ, Department of the Army
ATTN: DALO-TSE (COL Holley)
Washington, DC 20310

4 Commander
US Army Materiel Command
ATTN: AMCDE-SE (Mr. Mohler)
5001 Eisenhower Avenue
Alexandria, VA 22333-0001

1 Commander
US Army Tank-Automotive Command
ATTN: AMSTA-RG (Mr. McClelland)
Warren, MI 48397-5000

1 Project Manager, Light Armored Vehicl
US Army Tank-Automotive Command
ATTN: AMCPM-LA
Warren, MI 48397-5000

1 Commander
US Army Laboratory Command
ATTN: AMSLC-TP-PB (Mr. Gaul)
Adelphi, MD 20783-1145

1 Commander
US Army Depot Systems Command
ATTN: AMSDS-RM-EFO
Chambersburg, PA 17201

1 Director
AMC Packaging, Storage, and
Containerization Center
ATTN: SDSTO-TE-S
Tobyhanna, PA 18466-5097

1 Commander
AMC Materiel Readiness Support Activity
ATTN: AMXMD-MO (Mr. Brown)
Lexington, KY 40511-5101

1 Commander
US Army LEA
ATTN: LOEA-PL
New Cumberland Army Depot
New Cumberland, PA 17070-5007

3 HQ, US Army Test and Evaluation Command
ATTN: AMSTE-TA-L (Live Fire Office)
ATTN: AMSTE-CM-R-O
ATTN: AMSTE-TE-T (Mr. Ritondo)
Aberdeen Proving Ground, MD 21005-5006

1 Project Manager
Petroleum and Water Logistics
ATTN: AMCPM-PWL
St. Louis, MO 63120-1798

2 Commander
US Army Troop Support Command
ATTN: AMSTR-ME
ATTN: AMSTR-S
4300 Goodfellow Blvd.
St. Louis, MO 63120-1798

1 Commander
US Army General Materiel & Petroleum Activity
ATTN: STRGP-F (Mr. Ashbrook)
New Cumberland, PA 17070-5008

1 Product Officer
Amphibious & Water Craft
ATTN: AMCPM-AWC-R
4300 Goodfellow Blvd.
St. Louis, MO 63120-1798

1 Commander
US Army General Materiel & Petroleum Activity
ATTN: STRGP-PW (Mr. D. Eccleston)
Bldg. 247, Defense Depot Tracy
Tracy, CA 95376-5051

1 Commander
US Army Cold Region Test Center
ATTN: STECR-TA
APO Seattle 98733

1 Commander
US Army Combat Systems Test Activity
ATTN: STECS-EN-T
Aberdeen Proving Ground, MD 21005-5059

1 Commander
US Army Yuma Proving Ground
ATTN: STEYP-MT-TL-M (Mr. Doebbler)
Yuma, AZ 85364-9130

1 Commander
Theater Army Materiel Mgmt Center
(200th)-DPGM
Directorate for Petrol Management
ATTN: AEAGD-MMC-BM-Q
APO New York 09052

2 Commander
US Army Europe and Seventh Army
ATTN: AEAGG-FMD
ATTN: AEAGD-TE
APO New York 09403

1 Commander
Construction Engineering Research Laboratory
ATTN: CECER-EN
P.O. Box 4005
Champaign, IL 61280

1 HQ, Department of the Army
ATTN: DAEN-DRM
Washington, DC 20310

5 Program Executive Officer
US Army Tank-Automotive Command
Heavy Forces Modernization
ATTN: AMCPEO-CCV-S, APEO System
ATTN: AMCPM-ABMS, PM Abrams
ATTN: AMCPM-BFVS, PM BFVS
ATTN: AMCPM-M9, PM M9 ACE
ATTN: AMCPM-IRV, PM IMP REC VEH
Warren, MI 48397-5000

3 Program Executive Officer
US Army Tank-Automotive Command
Combat Support
ATTN: AMCPM-TVL, PM Light Tactical Vehicle
ATTN: AMCPM-TVM, PM Med Tactical Vehicle
ATTN: AMCPM-TVH, PM Heavy Tactical Vehicle
Warren, MI 48397-5000

1 DOD Project Manager, Mobile Electric Power
US Army Troop Support Command
ATTN: AMCPM-MEP-TM (COL Bramlette)
7500 Backlick Road
Springfield, VA 22150

1 Project Manager
US Army Missile Command
Patriot Project Office
ATTN: AMCPM-MD-T-C
Redstone Arsenal, AL 35898

3 Commander
US Army Forces Command
ATTN: AFLG-REG
ATTN: FCSJ-SA
ATTN: AFLG-POP
Fort McPherson, GA 30330-6000

1 TRADOC Liaison Office
ATTN: ATFE-LO-AV
4300 Goodfellow Blvd.
St. Louis, MO 63120-18=798

2 HQ, US Army Armor Center
ATTN: ATSB-CD-ML
ATTN: AFSB-TSM-T
Fort Knox, KY 40121

2 Commander
US Army Quartermaster School
ATTN: ATSM-CDM
ATTN: ATSM-LLFSD
Fort Lee, VA 23801-6000

1 Commander
US Army Field Artillery School
ATTN: ATSF-CD
Fort Sill, OK 73503-5600

1 Commander
US Army Tranportation School
ATTN: ATSP-CD-MS
Fort Eustis, VA 23604-5000

1 Commander
US Army Infantry School
ATTN: ATSH-CD-MS
Fort Benning, GA 31905-5000

1 Product Manager
US Army Tank-Automotive Command
Commercial Construction Equipment/SMHE
ATTN: AMCPM-TVC
Warren, MI 48397-5000

2 Product Manager
US Army Tank-Automotive Command
M113 FOV/M60 FOV
ATTN: AMCPM-M113
ATTN: AMCPM-60
Warren, MI 48397-5000

1 Commander
US Army Engineer School
ATTN: ATSE-CD
Fort Leonard Wood, MO 65473-5000

1 Commander
US Army Ordnanace Center and School
ATTN: ATSL-CD-CS
Aberdeen Proving Ground, MD 21005

1 Chief
US Army Logistics Assistance Office,
LAO-CONUS
ATTN: AMXLA-CO
Fort McPherson, GA 30330-6000

1 Commander
TRADOC Combined Arms Test Activity
Fort Hood, TX 76544

1 Commander
US Army Safety Center
ATTN: PESC-SSD
Fort Rucker, AL 36362

1 Commander
US Army Western Command
ATTN: APLG-TR
Fort Shafter, HI 96858-5100

1 CINC
US Special Operations Command
ATTN: SOJ4-P
MacDill AFB, FL 33608

1 Commander
US Central Command
ATTN: CINCCEN/CC J4-L
MacDill AFB, FL 33608

1 Director
Belvoir Fuels & Lubricants Research
Facility (SwRI)
ATTN: M. S. J. Lestz
P. O. Drawer 28510
San Antonio, TX 78284

1 HQ, European Command
ATTN: J4/7-LJPO (LTC Golla)
Vaihingen, GE
APO New York 09128

Department of the Air Force

1 HQ, Air Force Systems Command
ATTN: LGTV (Mr. Detweiler)
Andrews AFB, MD 20334

2 Commander
San Antonio Air Logistics Center
ATTN: SAALC/SFT (Mr. Makris)
ATTN: SAALC/MMPRR
Kelly AFB, TX 78241

1 Commander
Warner Robins Air Logistics Center
ATTN: WRALC/MMTV
ATTN: WRALC/MMVR (Mr. Perazzola)
Robins AFB, GA 31098

1 Commander
USAF 3902 Transportation Squadron
ATTN: LGTVP (Mr. Vaughn)
Offutt Air Force Base, NE 68113

1 MEEP
3200 SPTW/LGTE
Eglin AFB, FL 32542-5000

Department of the Navy

1 Department of the Navy
HQ, US Marine Corps
ATTN: LPP-2 (MAJ Nicholl)
Washington, DC 20350

1 Project Manager
US Army Tank-Automotive Command
M60 Tank Development
ATTN: USMC-LNO
Warren, MI 48397-5000

1 Commanding General
Fllet Marine Force Pacific
ATTN: G4
Camp H. M. Smith, HI 96861

1 Commanding General
Fleet Marine Force Atlantic
ATTN: G4
Norfolk, VA 23511

1 Deputy Commanding General
USMC Research, Development &
Acquisition Command
ATTN: Code CBAT (LTC Varela)
Quantico, VA 22134

1 Commanding General
USMC Research, Development &
Acquisition Command
ATTN: Code SS
Washington, DC 20380-0001

Department of Defense

3 Commander
Defense General Supply Center
ATTN: DGSC-SSC (Mr. Doyle)
ATTN: DGSC-STC
ATTN: STBA (Mr. Myers)
Richmond, VA 23297-5000

1 Commander
Defense Logistics Agency
ATTN: DLA-SEP-HMMIN (MAJ Nowinski)
Cameron Station
Alexandria, VA 22304-6179

Belvoir RD&E Center

Circulate

1 Commander STRBE-Z
Deputy Commander STRBE-ZD
Technical Director STRBE-ZT
Assoc Tech Dir (E&A) STRBE-ZTE
Assoc Tech Dir (R&D) STRBE-ZTR
Executive Officer STRBE-ZX
Sergeant Major STRBE-ZM
Advanced Systems Concept Dir STRBE-H
Program Planning Div STRBE-HP
Foreign Intelligence Div STRBE-HF
Systems and Concepts Div STRBE-HC
10 STRBE-V
20 STRBE-VU
3 Tech Reports Ofc ASQNK-BVP-G
3 Security Ofc (for liaison officers) STRBE-S
2 Technical Library STRBE-BT
1 Public Affairs Ofc STRBE-I
1 Ofc of Chief Counsel STRBE-L